Status of the CMS Experiment

LATBauerdick/Fermilab

Fermilab PAC Meeting Oct 20, 2006

Outline

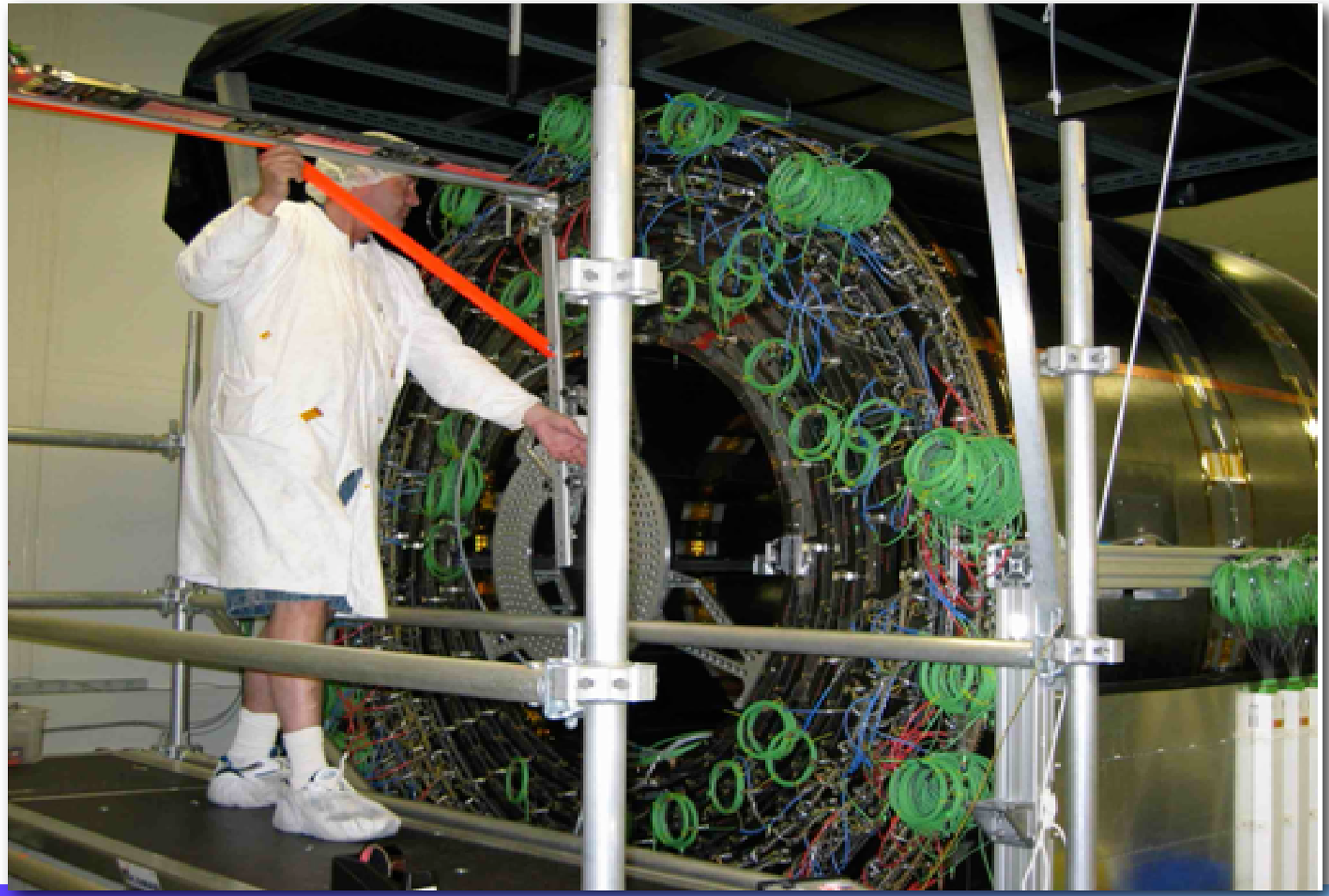
- Progress on CMS detector components
  - ★ in particular U.S. deliverables
- Progress on global CMS
  - ★ Magnet Test and Cosmic Challenge (MTCC)
  - ★ Software and Computing
- Evolution of CMS Organization

HCAL Forward (HF)

- HF moved into SX5 this summer.
  - Waiting for infrastructure to be ready above ground before lowering is scheduled – now in October

TOB - 100m2 Silicon

- The **Tracker Outer Barrel** is completed, tested, shipped to CERN
  - ★ for integration and commissioning in the Tracker Integration Facility

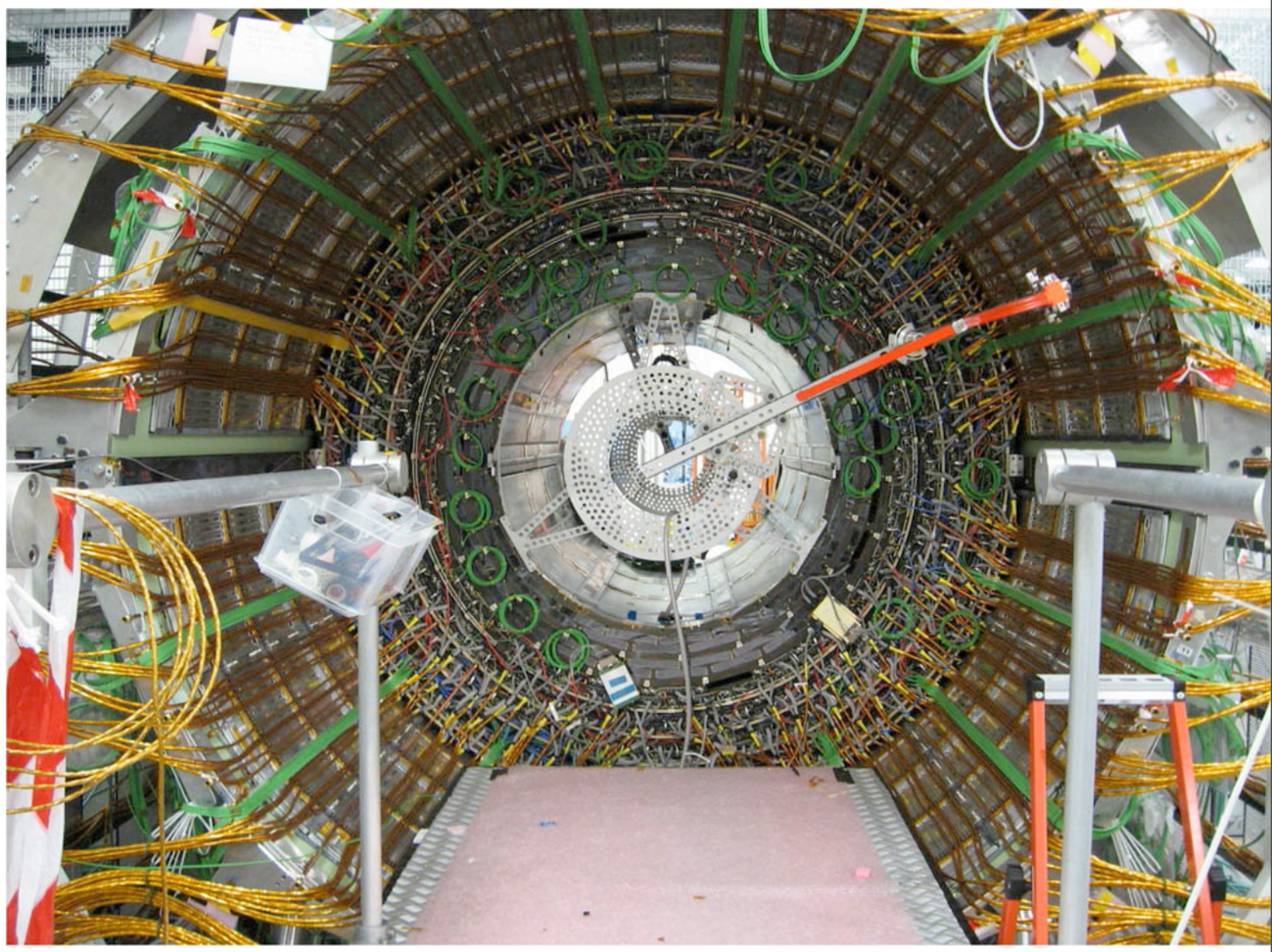


FPIX - Coming Now in 2007

- New plan for Pixels is to install a “slice” for the 2007 run to gain crucial operational experience – thus advancing the schedule for Pixel commissioning with interactions.
- FPIX project was baselined in Sep
  - Cost To Completion $4.0M$, Contingency $2.6M

Tracker Integration Status

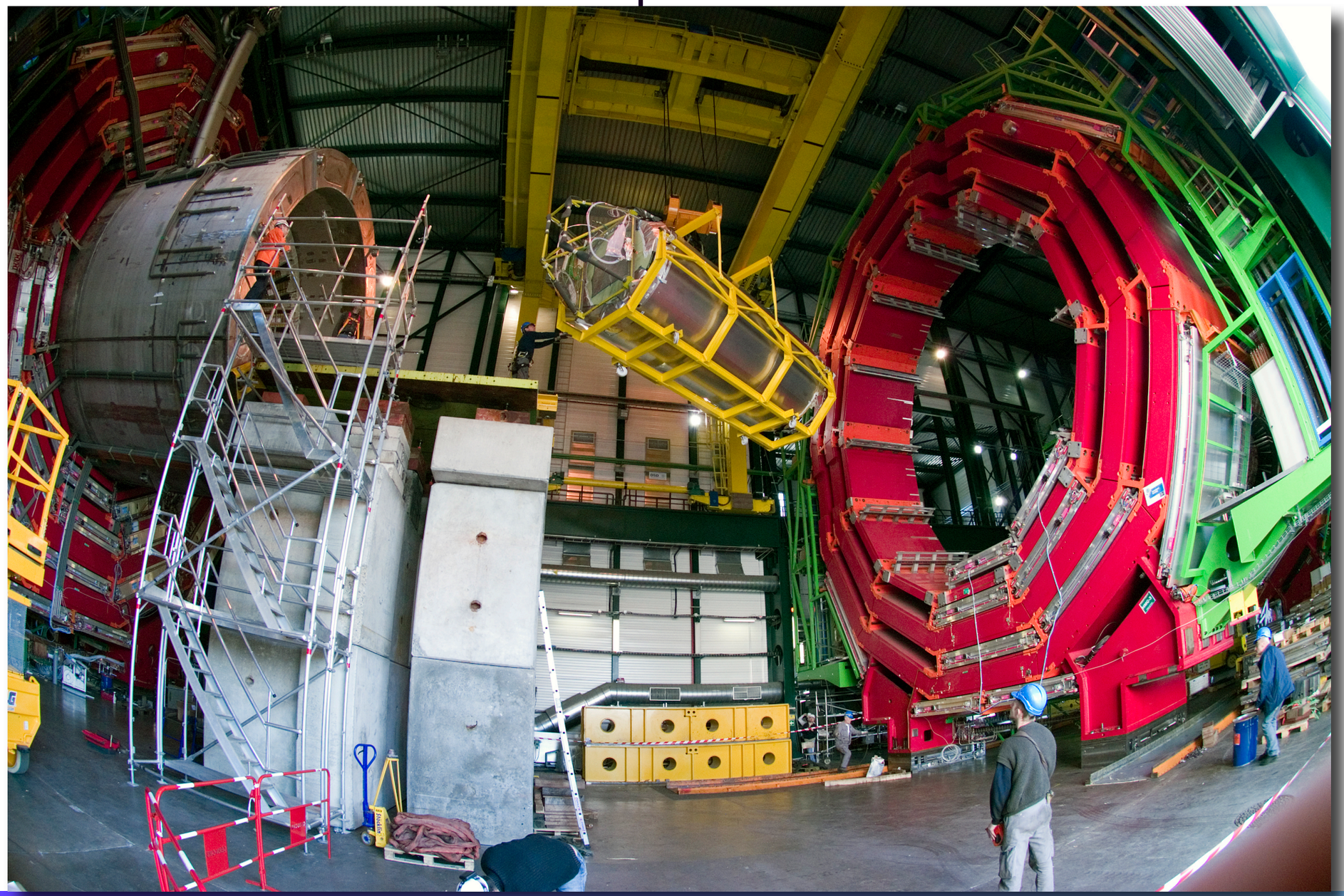
- ★ The **Tracker Integration Facility** is fully operational at CERN
- ★ TOB, TIB and TEC will be inside support tube by end 2006
- ★ Jan-May 2007:Commissioning TK in TIF (in steps of 2.5M channels)
- ★ Jun 2007: Transport Tracker fully commissioned to P5



- ★ Pixel modules are in production (15% done)
- ★ Pixel sector delivered to CERN in Dec 2006 for integration in TIF before installation into CMS in Sep 2007
- ★ Full Pixel detector ready for installation in Nov 2007

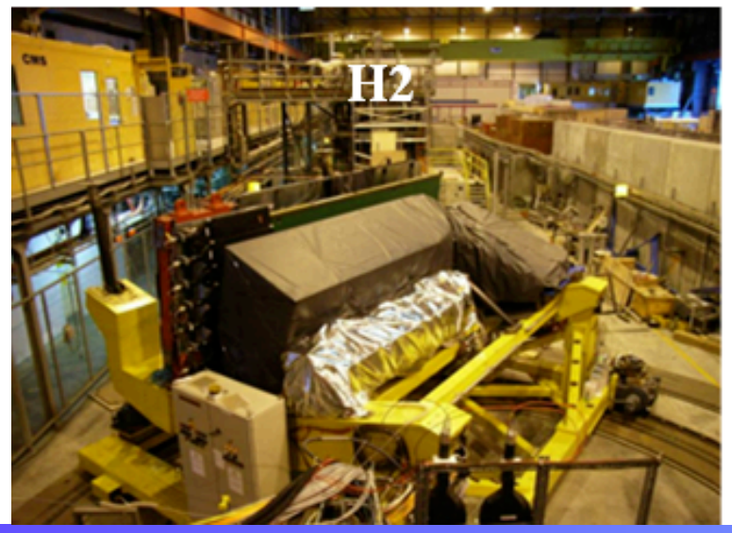
Tracker Rigged into Magnet

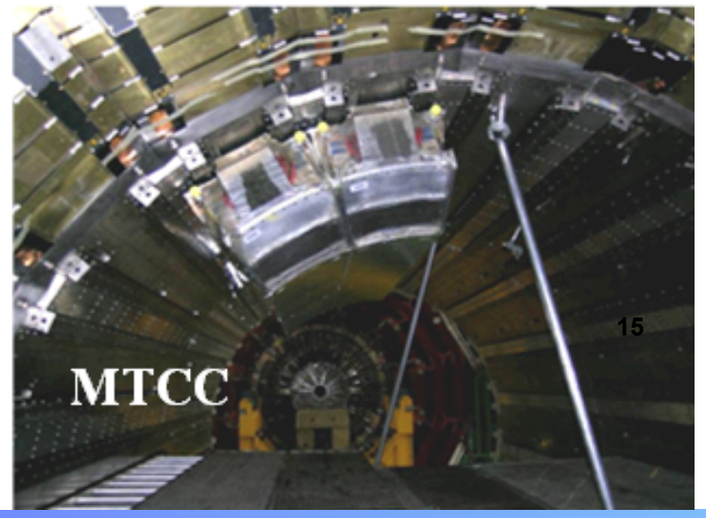
- The Tracker built elements of the final (1% of total) detector in order to get operational experience in the MTCC.
  - ★ The volume was full sized to do a practice insertion.



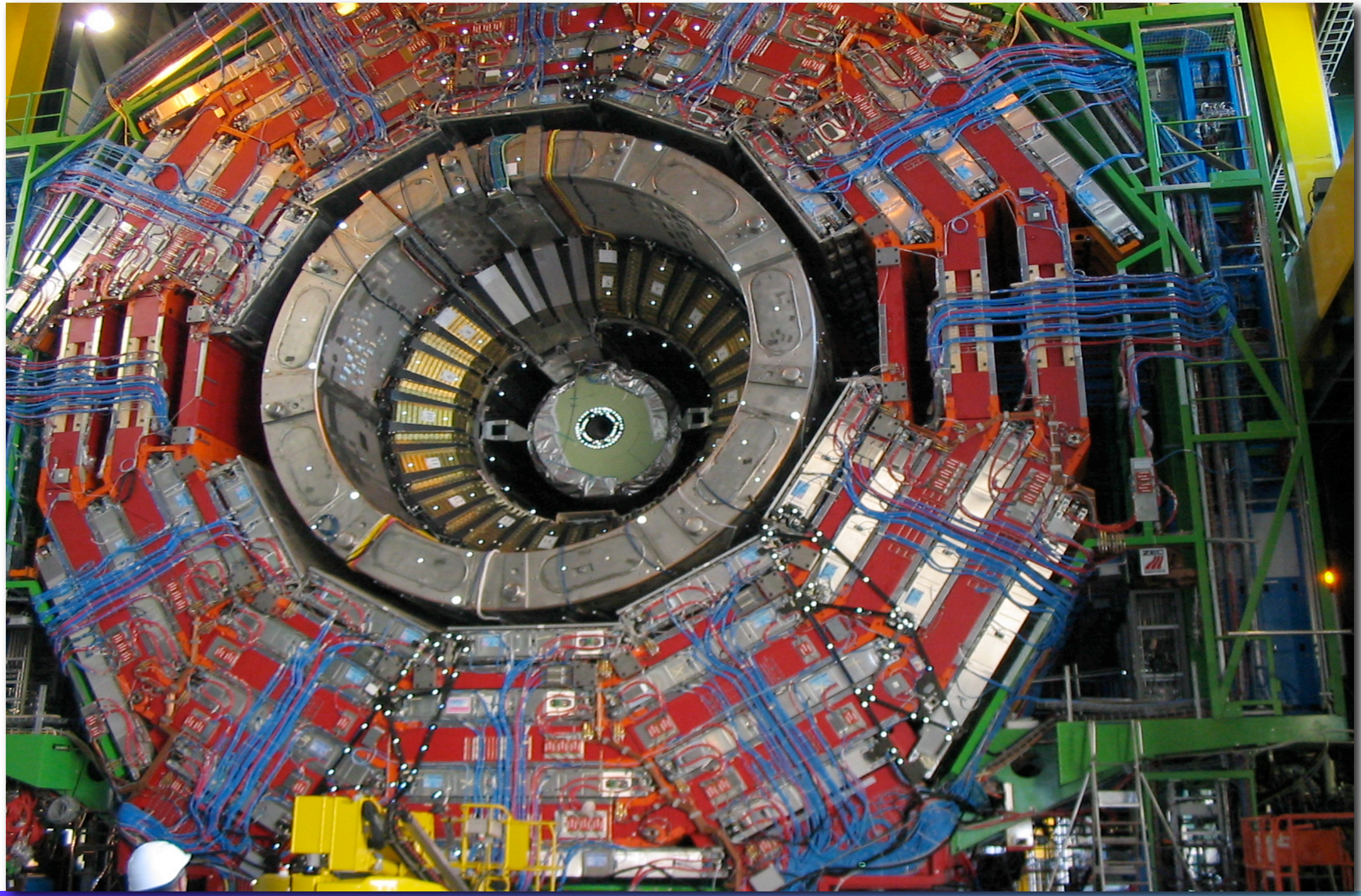
ECAL Schedule

- Barrel (EB)
  - ★ EB+ installation into HB+ starts in November
    - all 18 SuperModules are available
  - ★ EB– installation follows on surface until January 2007
  - ★ Last EB crystal expected end of February
    - last SuperModule by early May
- Endcaps (EE)
  - ★ EE crystal production starts in October (China) and March (Russia)
  - ★ Aim is to have part of EE1 for pilot run in 2007
  - ★ Aim is to have complete EE installed for physics run in 2008

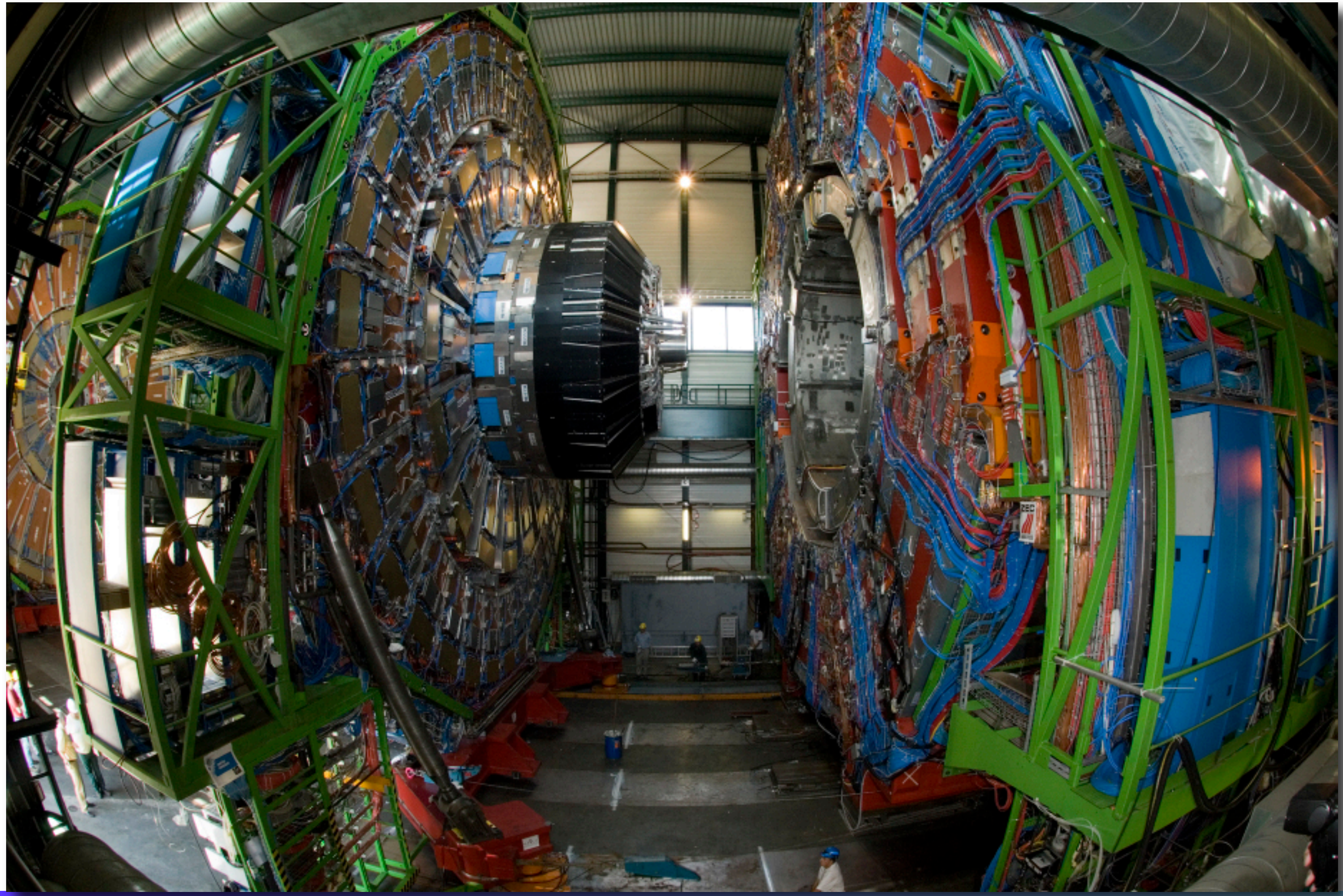




CMS Barrel ready for Magnet Test (July)

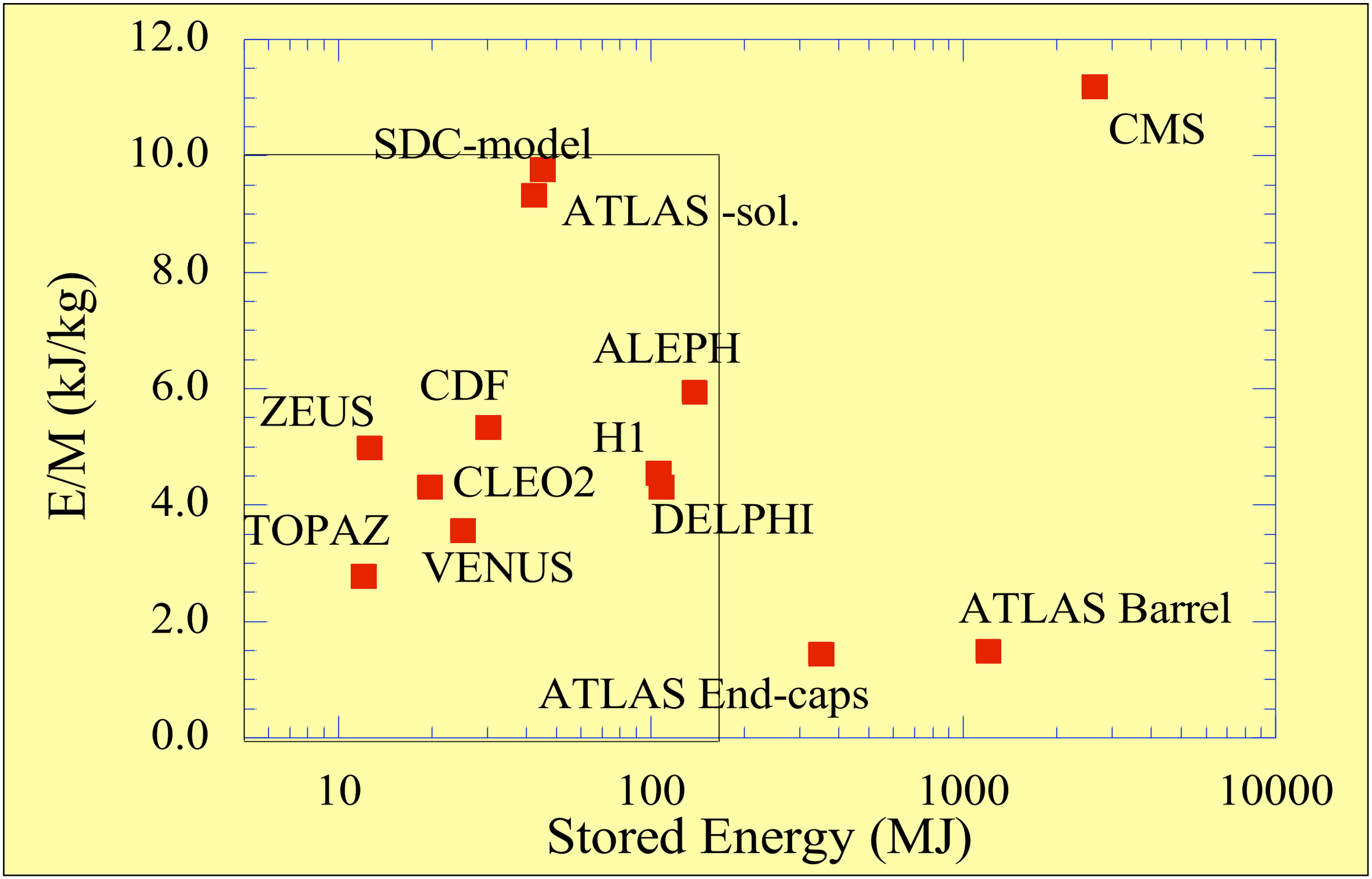


Closing CMS the first time (July)



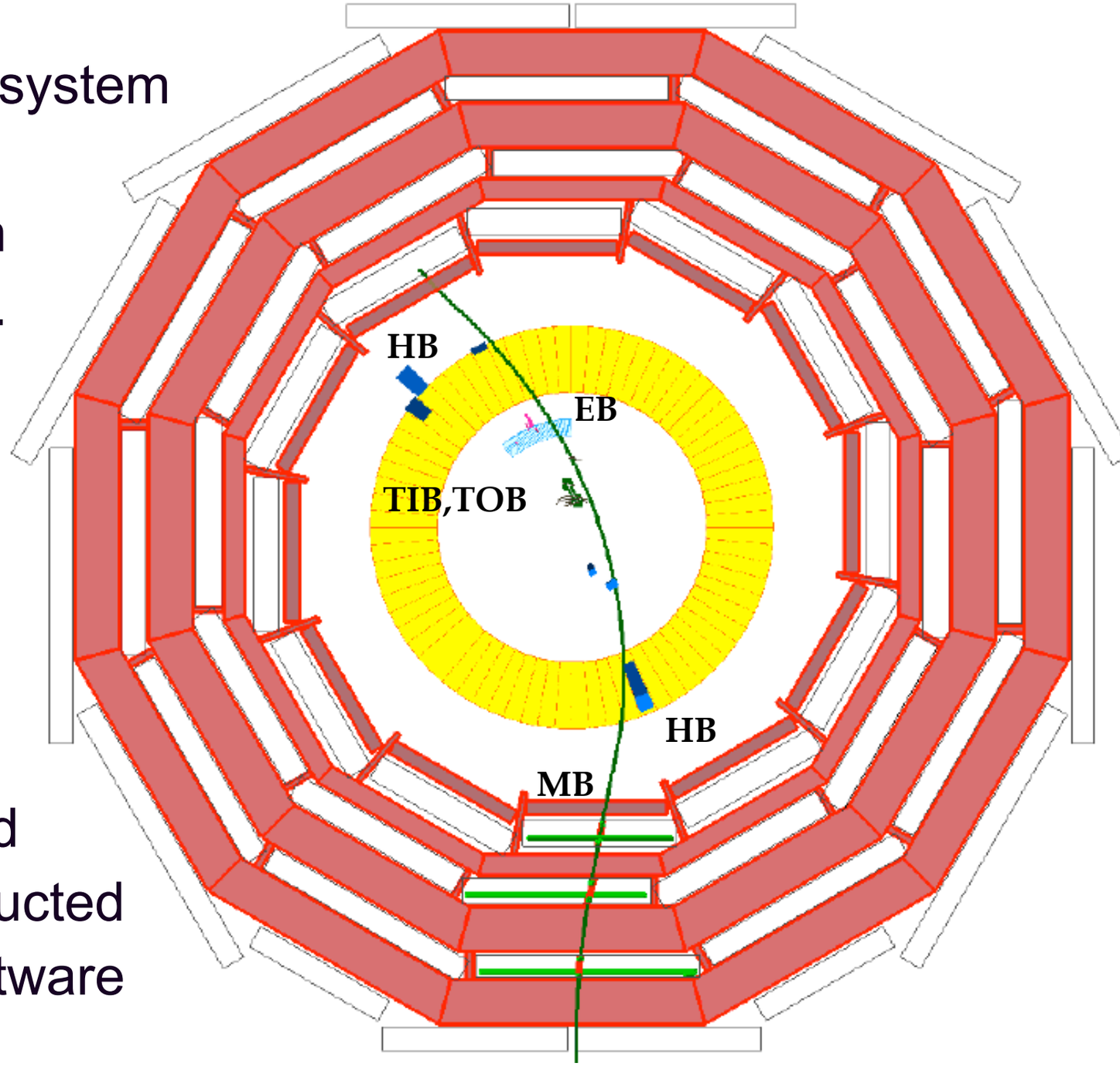
Magnet is ~ 3 GJ

- CMS is the world's largest electromagnet — stable working at 4T



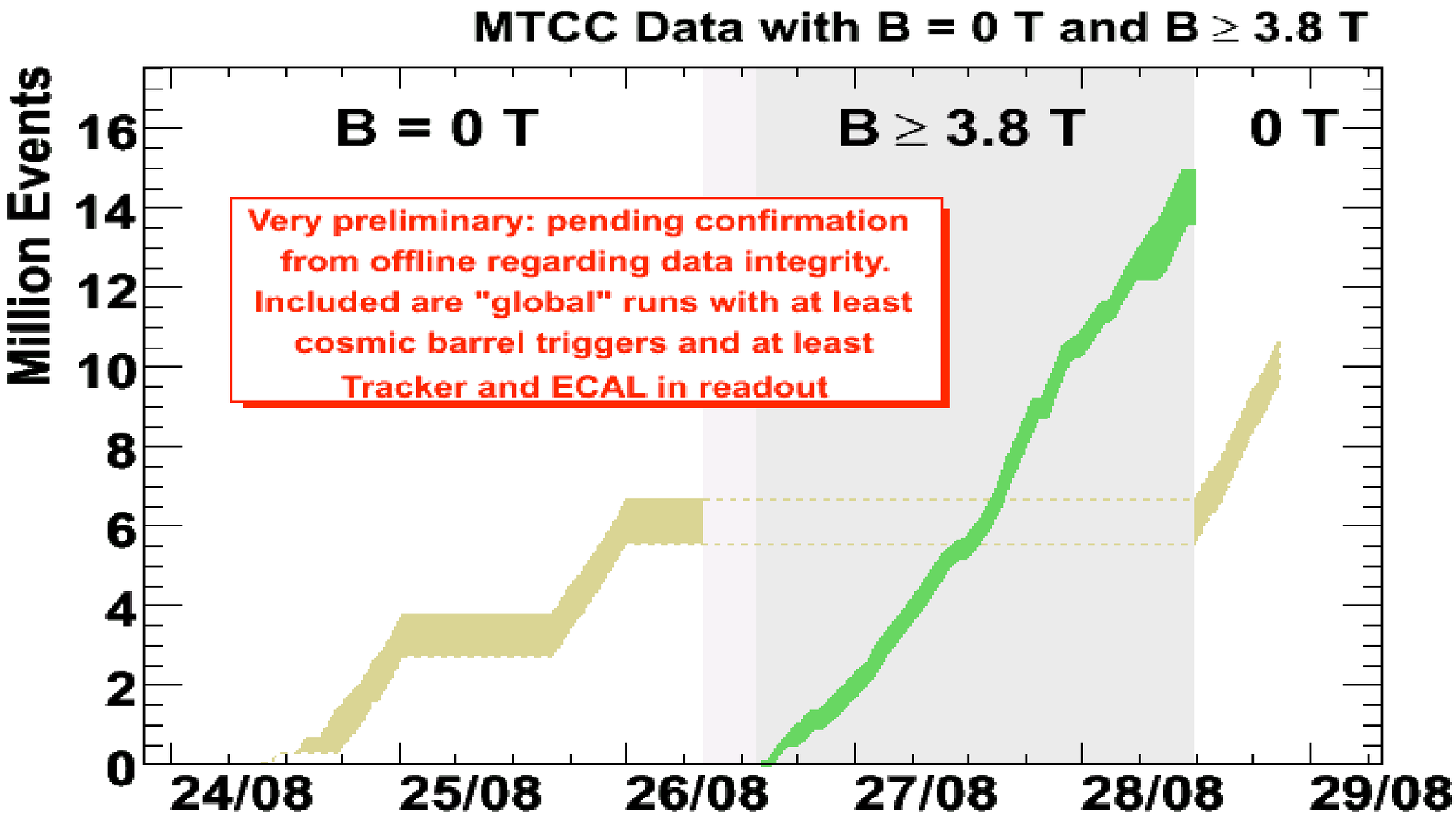
Magnet Test and Cosmic Challenge

- ★ All Key objectives of MTCC met!
- ★ Test magnet to 4T
- ★ jointly read out each CMS subsystem with cosmic ray muons.
- ★ All CMS subsystems logged in global DAQ and synchronized.
- ★ This is a major milestone on the way to CMS data taking!
- ★ Muons can be used to cross check HB and HE calibration and to align the muon chambers.
- ★ events written in re-engineered EventDataModel and reconstructed (and displayed) using new software framework CMSSW



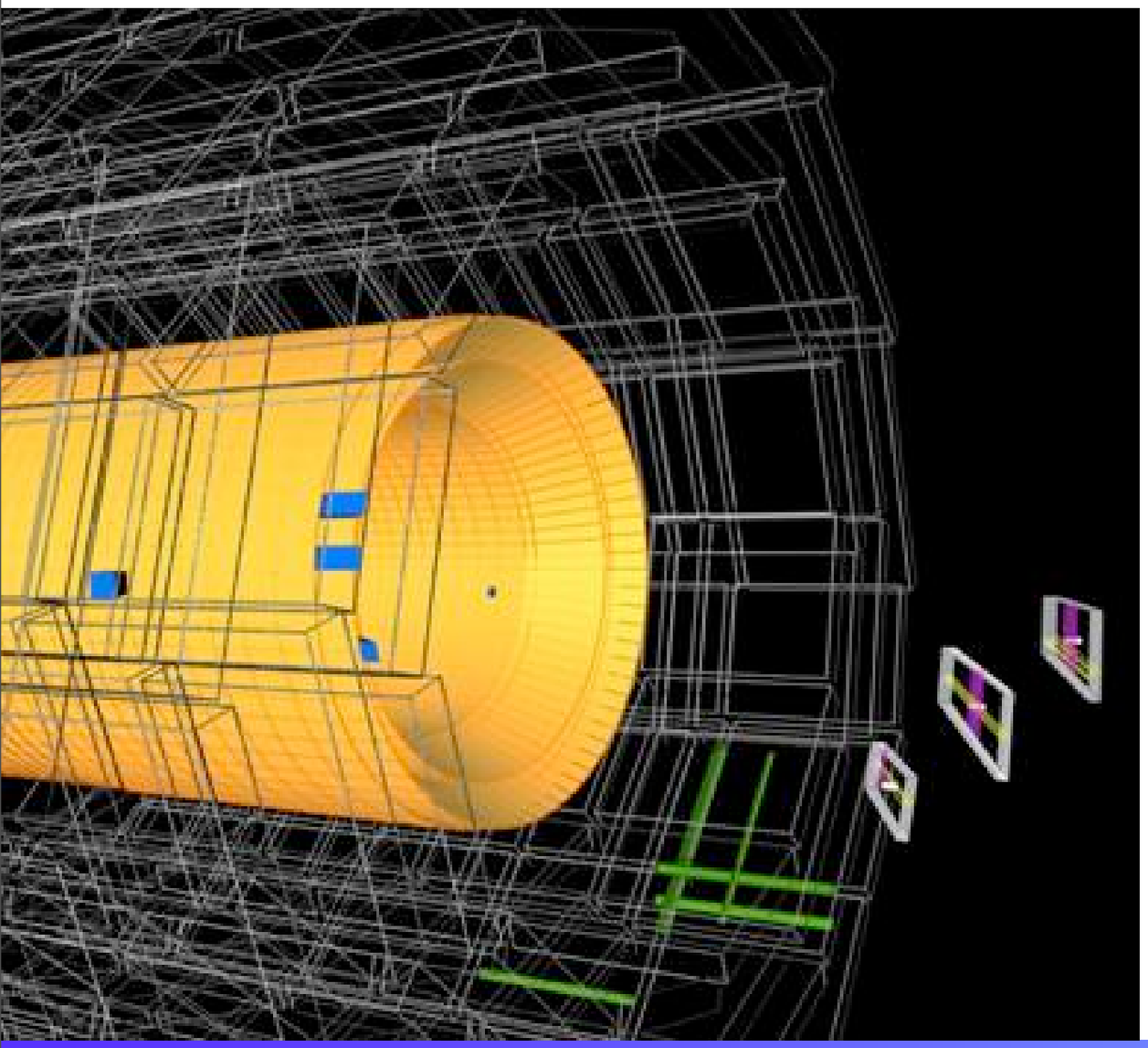
MTCC Data Taking

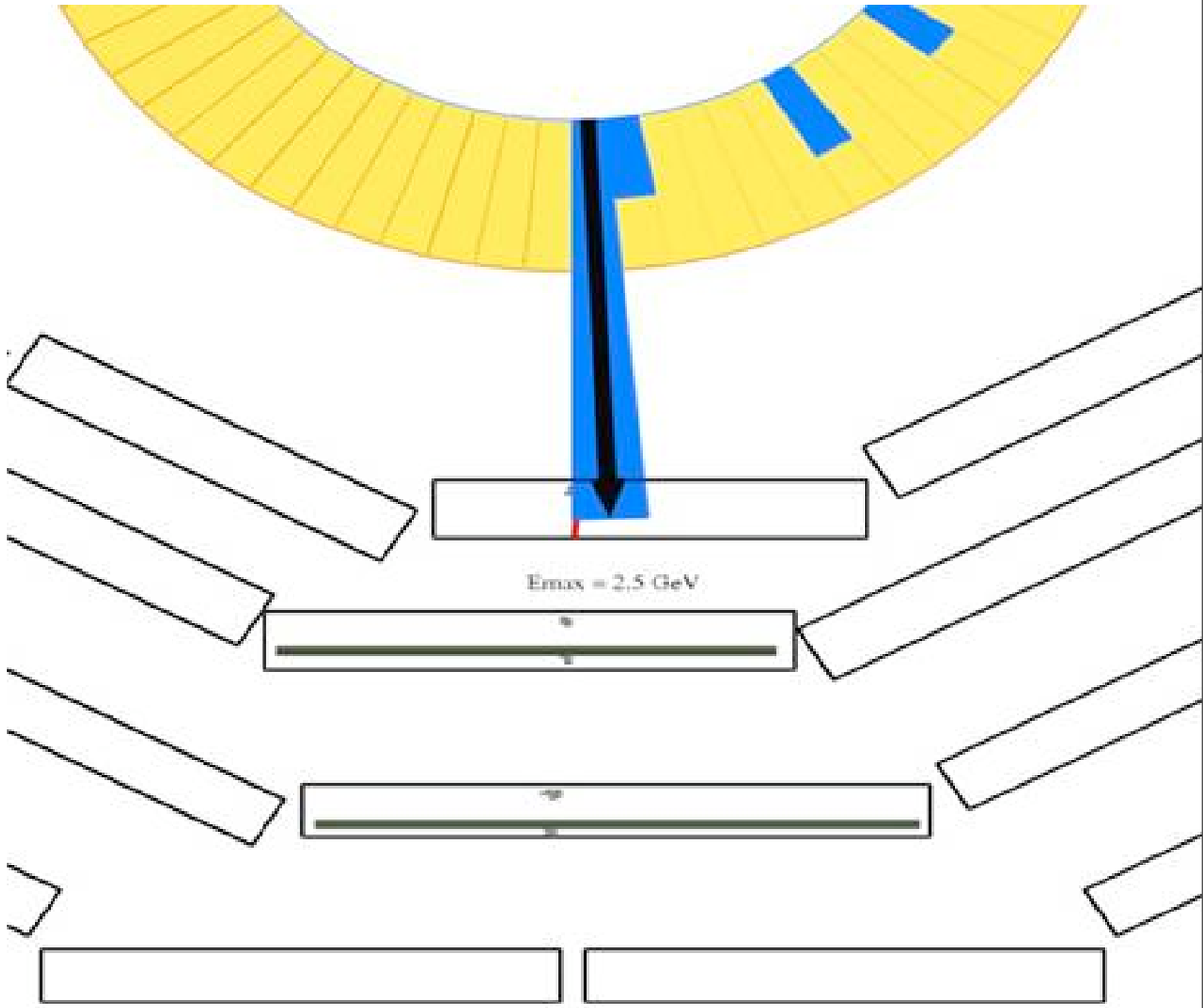
- ★ Collected > 25 M events in roughly 4 days
- ★ Trigger: barrel (DT, RBC, RPC-TB) and endcap (CSC)
- ★ raw rates between 120 and 200 Hz, data taking efficiency ~ 90%



ME Muons and HB in MTCC

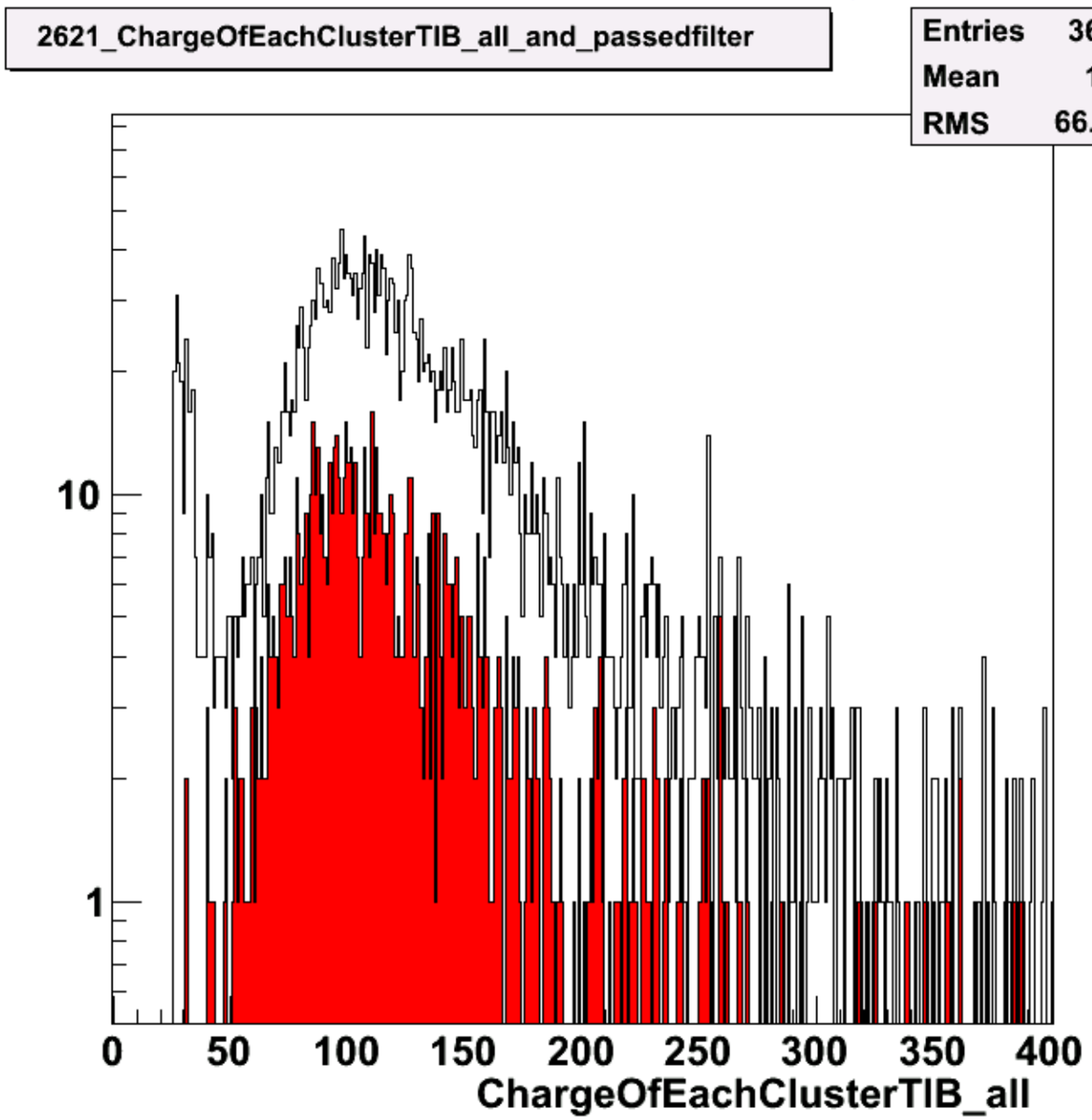
- All CMS subsystems sync-ed, global data taking w/ 1/8 DAQ slice
  - ★ timing studies, trigger studies, alignment studies, etc done
- Note CSC tracking, HB and MB data.





MTCC – Tracker Clusters

- Obtained S/N in the expected range
  - ~ 27 (TIB) ~ 45 (TOB,TEC).
- Track alignment and fitting are now in progress.



MTCC Data Taking

- ★ Reconstruction working on the Event Filter (mini) Farm at P5
  - ✦ CMSSW version 0.9.0 used on the event filter mini-farm
  - ✦ software worked from the event filter to visualization on real data taking
  - ✦ not only at local level but also at global level (tracker, muon-stand-alone reconstruction...) and in the last days also at global muon level.
  - ✦ plans for MTCC phase 2: improvements on storage manager, all detectors fully working on the filter farm.
- ★ All DataQualityMonitoring applications constantly ran offline
  - ✦ With 0.5-1 hr delay wrt data taking
  - ✦ Online DQM from parasitic online stream from the storage manager ran for most of the field-on period (HCAL, Tracker, CSC), monitoring LTC even in the farm
  - ✦ After MTCC phase 1, Muon DT, CSC and tracker integrated in the Filter Farm
- ★ The Detector Control System was in place during the MTCC
  - ✦ checked voltages, temps, etc.
- ★ Muon Alignment System tested
  - ✦ very good experience to understand the performance of the alignment system itself, the closing procedure and the yoke behavior under magnetic forces.

First Data Shifts at the ROC

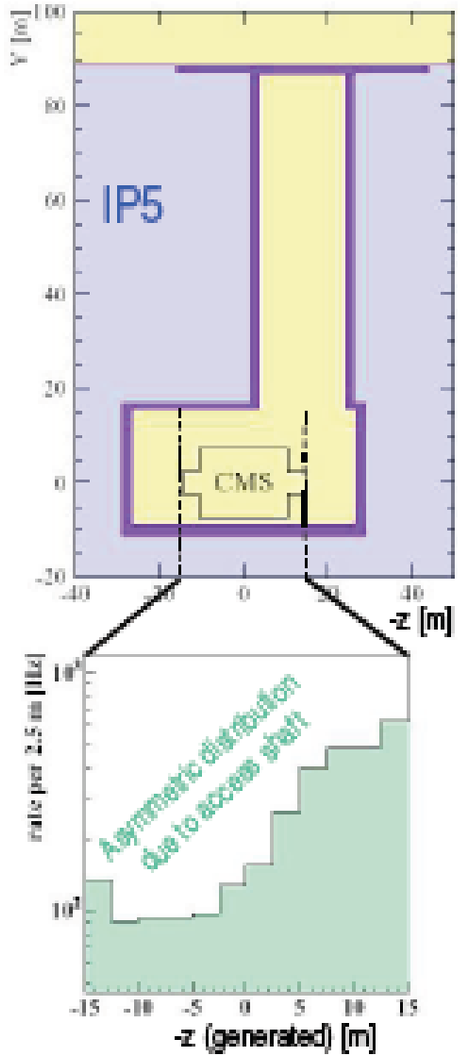
- Remote Operations Center at Fermilab
  - ★ place for U.S. people to do remote operations of detector
- Key participant in MTCC monitoring
  - ★ During MTCC, successfully exercised and established a foundation of quasi-online data monitoring and analysis
  - ★ Quasi-realtime data transfers from P5 to CERN-IT and from there to Fermilab Tier-1 and a number of Tier-2/3 centers
  - ★ Automatic and systematic running of event display and various DataQualityMonitoring programs (HCAL, Trigger, Tracker, CSC)
  - ★ Making the results (Histograms) of DQM programs readily and easily available to the sub-detector/DAQ/Trigger experts anywhere, during a run and also for all runs which were taken
- ROC stood ~ half of all MTCC data and DQM shifts!
- Construction proceeding for "LHC@FNAL"
  - ★ joint LHC/CMS "Control Room" on Wilson Hall 1st floor

MTCC Continues for Commissioning

- ★ Magnet was field mapped with good results
- ★ MTCC Phase II underway
- ★ Underground, MTCC will continue up until LHC beam arrives

"MTCC Phase III" – Cosmics Underground

- Highly energetic muons traversing the detector more-or-less vertically
  - Used in initial phase of commissioning, e.g. to establish coarse synchronization (like in MTCC)
  - Interesting for initial alignment/calibration of
    - (barrel) muon systems, tracker (barrel), barrel HCAL & ECAL, (& align. system compared to tracking alignement)
  - But: Cosmics are rather "rare" and they
    - are out of time (cannot unambiguously associated with clock; timing different e.g. for upper vs. lower detector sectors), and
    - do not (all) point to IP.



Preliminary rates for p_T^μ >10 GeV from simulation (use these numbers with care! Efficiency (timing and μ-direction) not yet applied & rates probably **much** lower; simulation accurate? → Needs to be verified)

$N_{HIT} \geq 1$	Rate[Hz]
CMS tot	~1800
Muon only	~1800
calorimeter	~ 700
tracker	~ 60

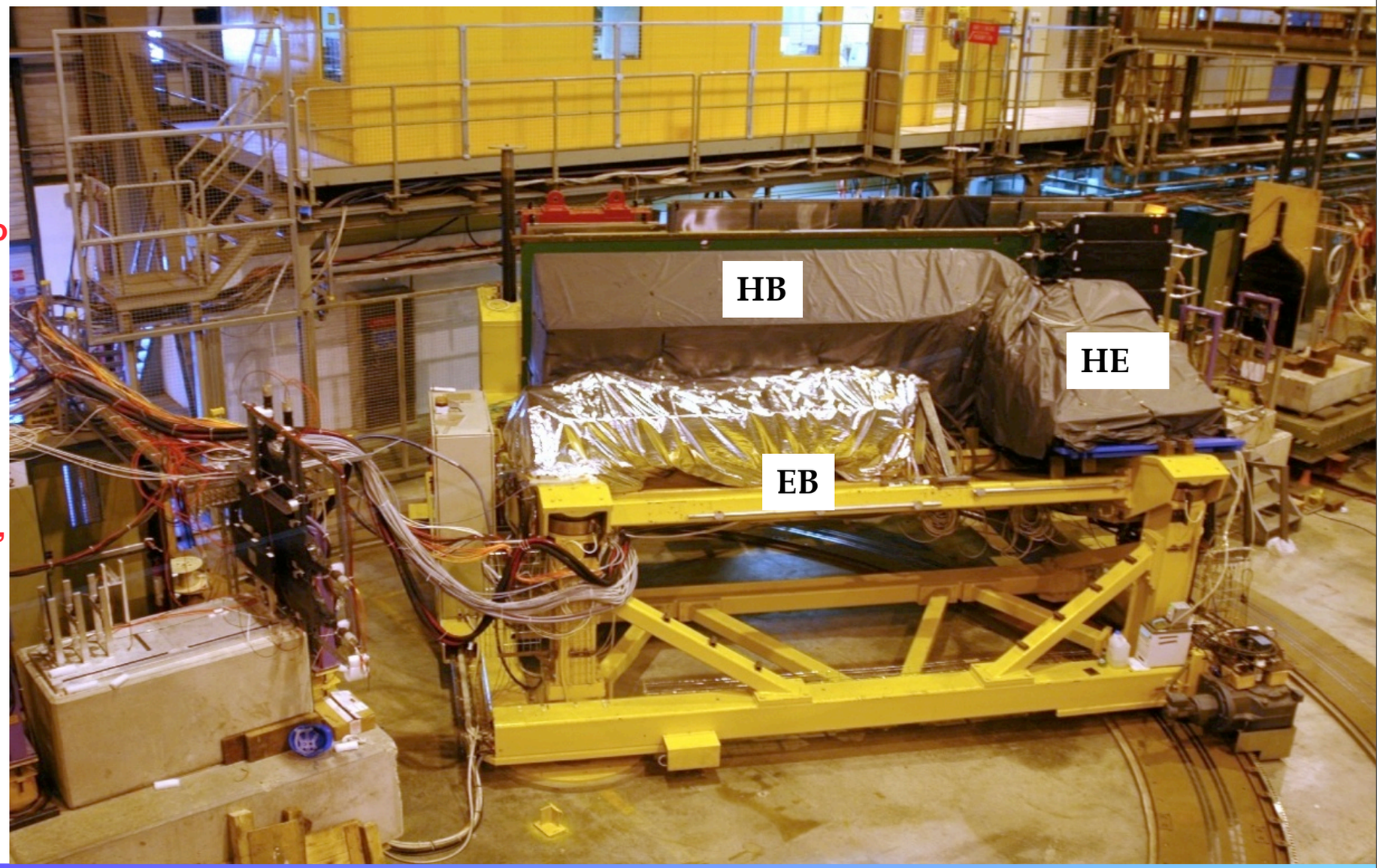
Test Beam 2006 - ECAL+HCAL

- Exercise a "real" HCAL+ECAL calorimetric system
- a lot of effort was put into TB2006

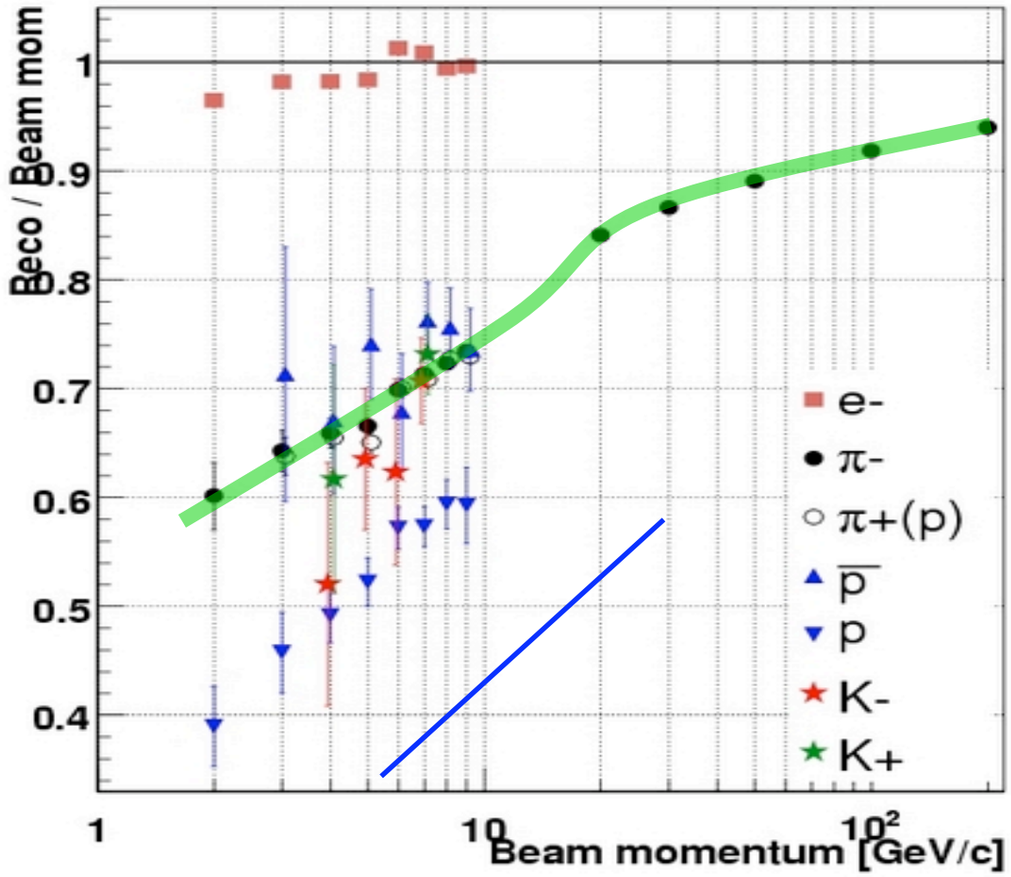
Very Low Energy (VLE) line is able to give 1 to 9 GeV/c h+, h-, e+ and e- with good rate, a few hundred/spill using a tertiary target (T22). At lower end of the range, particles are mostly electrons. There is a significant muon contamination as well.

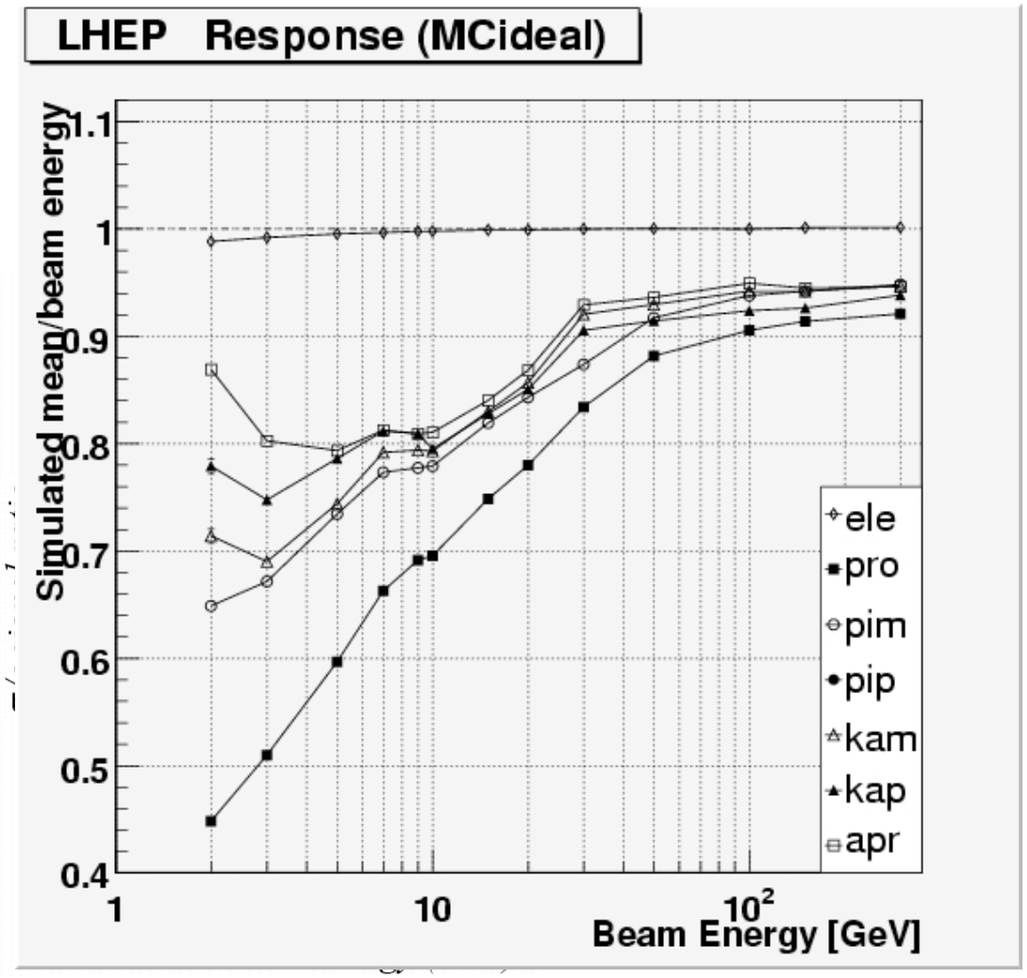
Particle ID is accomplished by TOFs, Cerenkovs and muon veto counters.

High energy line covers a momentum range from 10 to 300 GeV/c for hadrons through secondary particle production. For electrons/positrons, the range is 10 to 150 GeV/c.



Reconstructed Calorimeter Response





- ★ For the first time have a complete set of low energy data for pions, kaons and (anti)protons for the combined ECAL+HCAL
- ★ These data are essential to correctly estimate the jet response of the CMS calorimeter system.

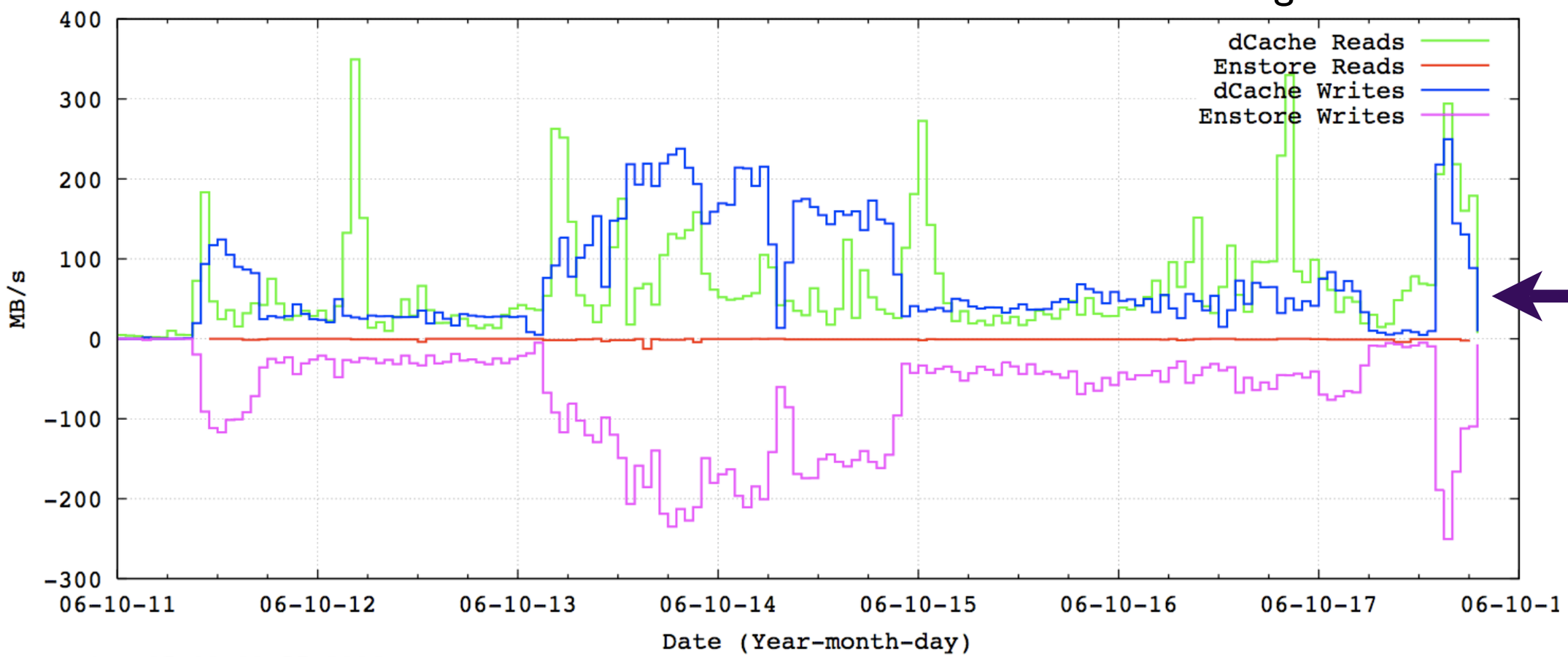
Status of Software and Computing

- ★ "Physics TDR" Vol1 and Vol2 published,
  - ✦ with ~ 200M events simulated, reconstructed and analyzed, for 85 analysis notes
- ★ CMS Software made major progress during this year:
  - ✦ create a new framework and event data model CMSSW
  - ✦ acquire ability to read detector with new Framework/EDM (tested in MTCC!)
  - ✦ introduce calibration and alignment into CMS software
  - ✦ develop and migrate simulation as well as local and global reconstruction SW
  - ✦ sequence of CMSSW releases, with release 1_0 being used in CSA06 Data Challenge
- ★ new Software, Data Management, MC Systems operational: SC4, CSA06
  - ✦ some 60M events simulated in preparation of CSA06,
  - ✦ reconstruction running at Tier-0 since 19 days now -- stably, w/ good performance
  - ✦ data transfers to Tier-1 and Tier-2 centers successful, after a lot of commissioning
  - ✦ Grid job success rates of up to 98% 25k Grid jobs/day feasible, goal is 50k/day
- ★ Seven Tier-2 sites in the U.S. commissioned + the Fermilab Tier-1 center have some 30 validated CMS sites worldwide
  - ✦ interoperability between OSG and EGEE is a reality, OSG is funded with $6M/year
- ★ Data Challenge/End-to-end System Test CSA06 in full swing

CSA06 Data Challenge

- ★ end-to-end test to establish “physics infrastructure” at 25% level of 2008
- ★ Tier-0 running CMSSW reconstruction software smoothly since start of challenge -- >80M events reconstructed
- ★ data transfers to Tier-1 centers, where data sets are being stored
- ★ skimming of analysis datasets at T1, transfer to T2, analysis jobs at T2
- ★ all 7 Tier1s, 24 Tier2s participating

Data Transfers Into and Out of Fermilab Tier-1 Storage



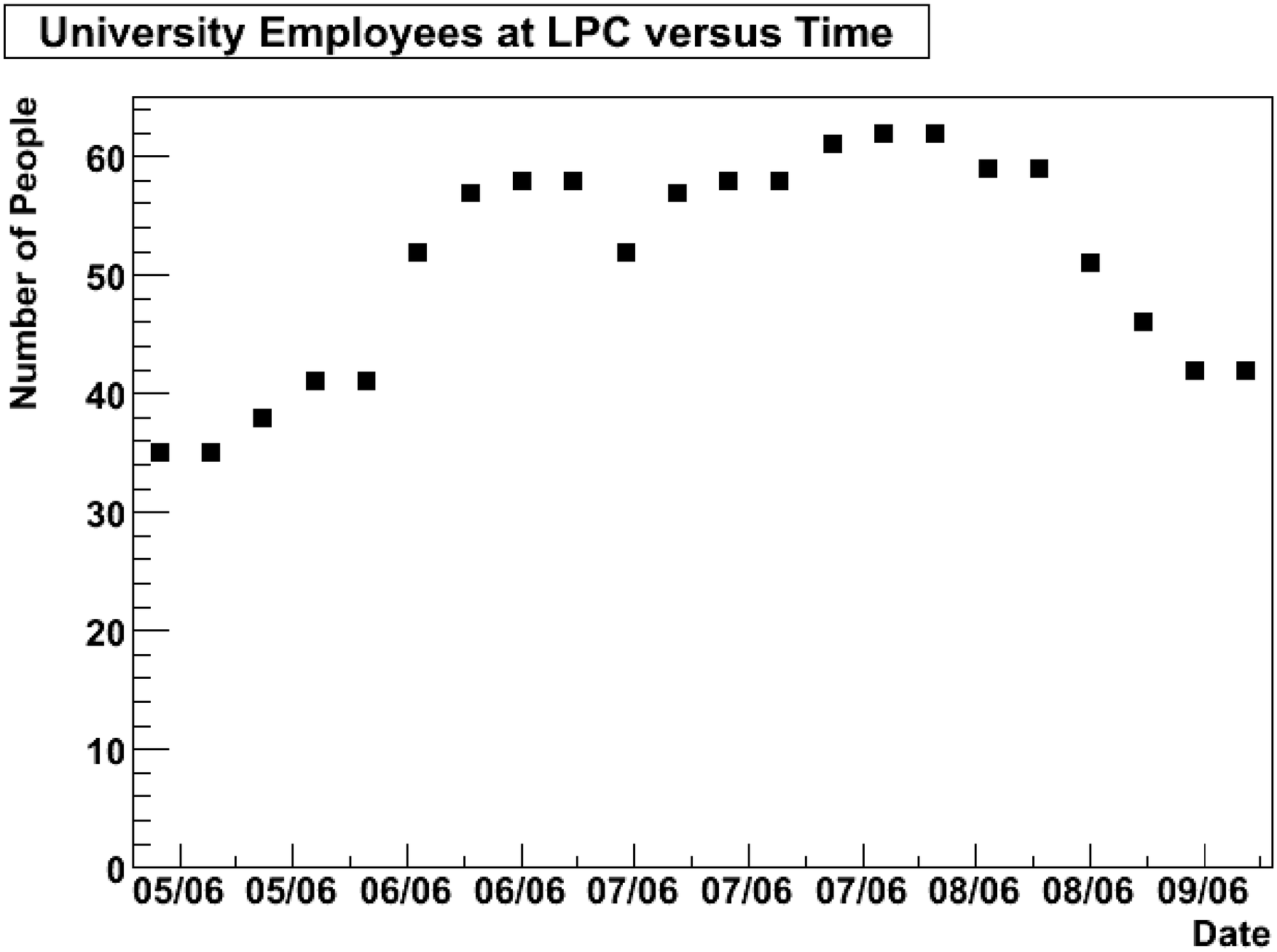
T0–T1 throughput goal

LPC - Status

- LPC managed to build a strong foundation at Fermilab
  - ★ the LPC now has made major contributors to current developments: framework, tracking, Jet, Met, code management,…
  - ★ Fermilab support has been and is very strong
  - ★ today LPC is one of the best places (if not the best) in terms of software expertise in CMS
- Examples for LPC activities
  - ★ Six active working groups
    - Recently added a "Physics group", *b*, and *tau* tagging
  - ★ Workshops, Schools, Meetings (a few highlights):
    - Hosted CMS Physics week, CMS Tracker/SW joint workshop,…
    - Introductory CMS101, J-term, Tutorials on new software
    - Weekly Physics meetings, MC samples created and maintained
    - Initiated the first joint FNAL/CERN HCSS, 07 at CERN, 08 back at FNAL

LPC Attractive for US Universities

- ~50 University Colleagues at LPC Throughout the Summer

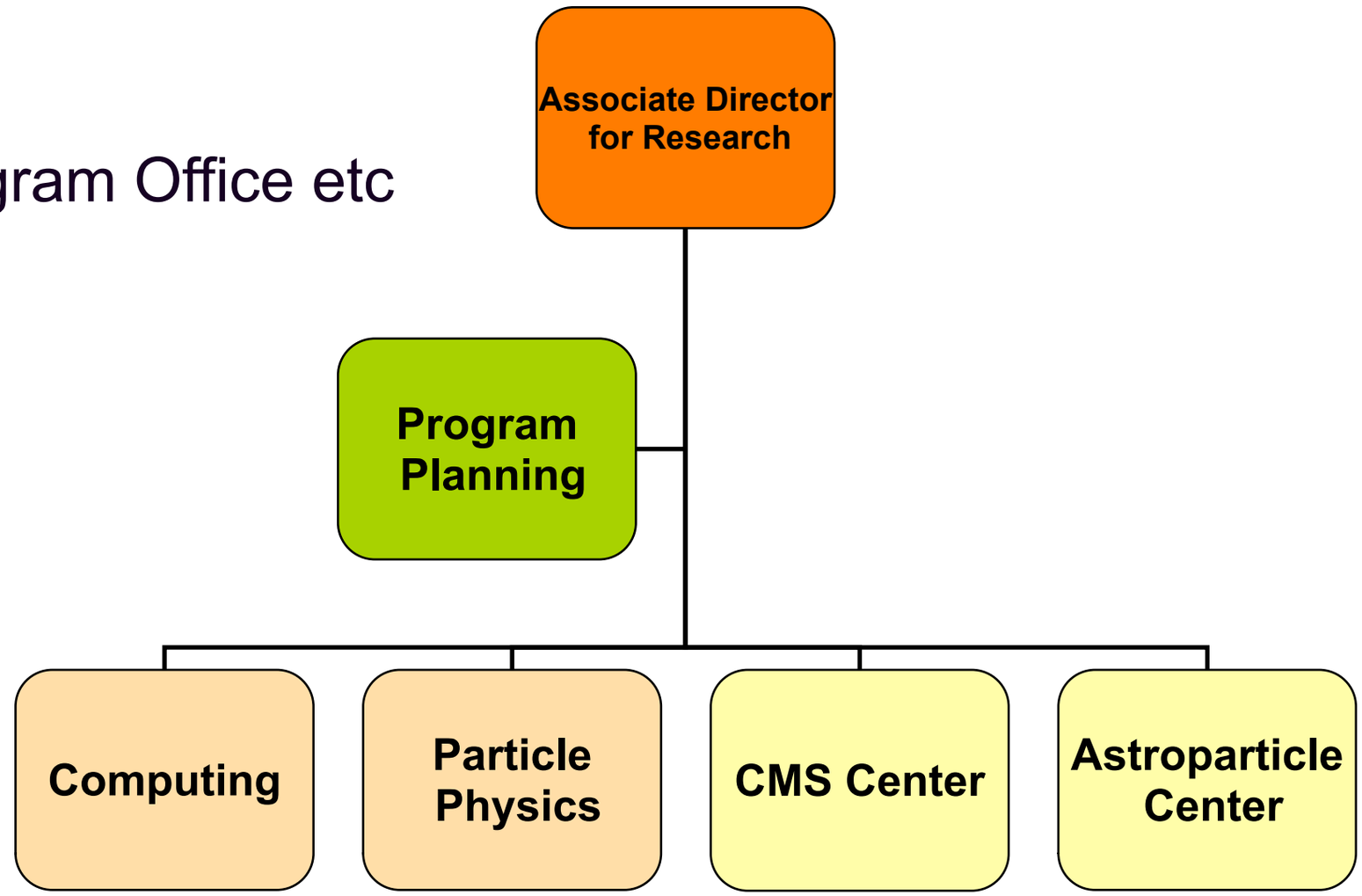


U.S. CMS Research Program

- U.S. Research Program receiving good marks in August review
  - ★ trust in management and approaches to solve problems
- DOE/NSF LHC program manager notes the increased pressures on the U.S. CMS program generated by
  - increase in M&O expenses through increase of U.S. collaborators,
  - additional computing costs,
  - calls for more U.S. contributions from experiments,
  - a 50% difference in #experimenters b/w U.S. Atlas and U.S. CMS
- DOE outyear funding guidance provided 5 yrs ago
- NSF funding plan approved by NSB through FY2011
- EPP-2101 and P5 Have Spoken: LHC, including its upgrades, is tops!
  - ★ should not be permitted to erode through inflation
- DOE funding guidance being updated to include a ~3% escalation
- Joel Butler will take over U.S. Research Program Manager

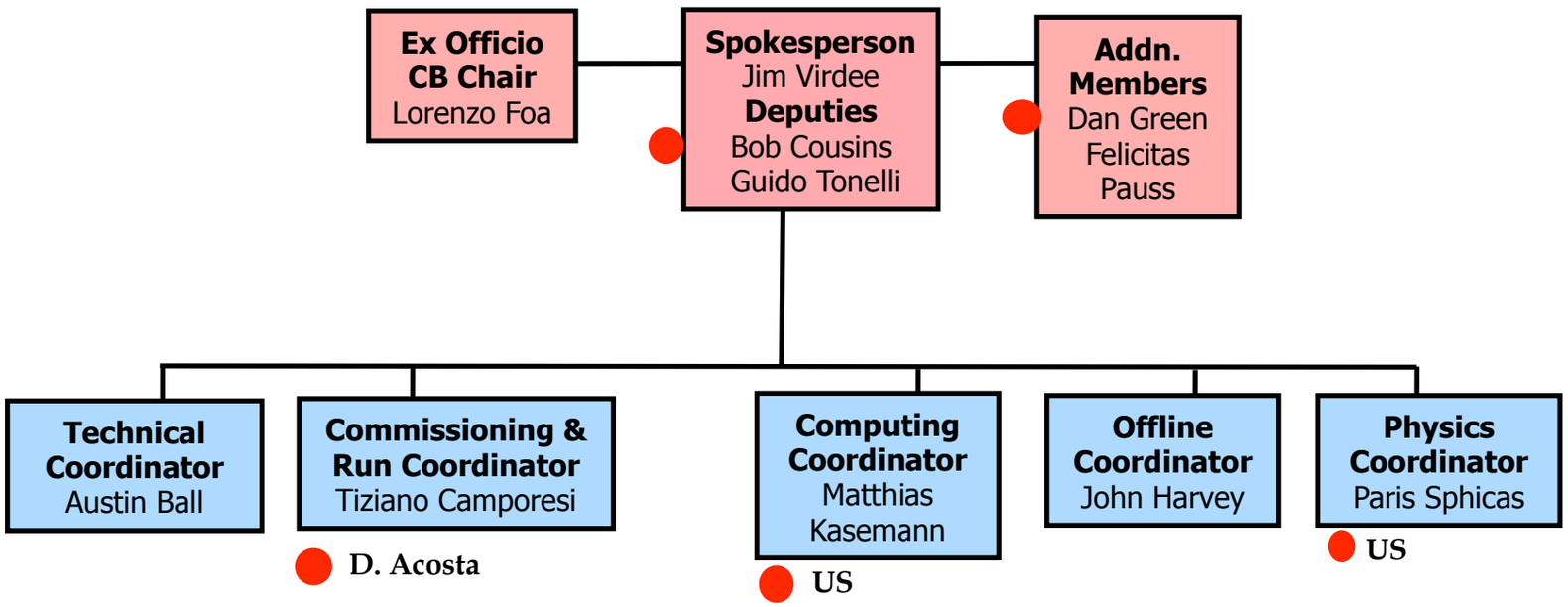
Fermilab Org Changes

- Fermilab is forming a CMS Center as part of Research Sector
  - ★ CMS visible on org-char of lab, forming a Fermilab CMS group
  - ✦ Coordinate, support Fermilab scientific staff involved in CMS as a unit
  - ★ collect and manage in one place overall resources for CMS at FNAL
    - ✦ matrix-ed work with divisions
  - ★ hosts the LPC, ROC
  - ★ administrative home of Research Program, Program Office etc



CMS - Reorganization

- New Spokesperson (Jim Virdee), new organization
  - Executive board will run experiment as a unit, transitioning from federated structure of subcomponents
  - exact structure of and interactions between areas being defined
  - U.S. involved on highest level CMS management



Summary

- CMS is coming together in terms of components, and as a whole experiment
  - ★ Over the summer, three critical objectives were achieved
  - 1) First closing of the experiment
  - 2) Solenoid tested to the design field of 4 Tesla
  - 3) Cosmic Ray events recorded in all sub-detectors working together
  - ➡ CMS can operate as a single coherent detector
  - ➡ CMS can operate as a worldwide and unified collaboration

- MTCC has been a great success in learning how to operate CMS.
- TestBeam2006 data set will provide many important checks of the Monte Carlo modeling of CMS.
- CMS is restructuring to confront data taking and analysis
  Fermilab is restructuring to place more emphasis on CMS

Backup Slides

450 GeV – Calibration Run

Operations' aims:

- **Commission essential safety systems**
- **Commission essential beam instrumentation**
- **Commission essential hardware systems**
- **Perform beam based measurements to check:**
  - Polarities
  - Aperture
  - Field characteristics
- **Establish collisions**
- **Provide stable two beam operation at 450 GeV**
- **Interleave collisions with further machine development, in particular, the ramp.**

Should provide a firm platform for eventual commissioning to 7 TeV and provide adequate lead time for problem resolution.

2007 machine schedule

	Phase	Beam time [days]	Beam
1	First turn	4	1 x Pilot
2	Establish circulating beam	3	1 x Pilot
3	450 GeV – initial	3	1 x Pilot++
4a	450 GeV - consolidation	1-2	1 x Pilot++
4b	450 GeV – system commissioning	2-3	1 x Pilot++
5a	2 beam operations	1	2 x Pilot++
5b	Collisions	1-2	2 x 1 x 10^{11} ➔
		16 days	

Given an operational efficiency of 60%, this gives an elapsed time of about 26 days. ***CAVAET: MACHINE AVAILABILITY***

Some opportunities for parallel development and parasitic studies…

450 GeV - Performance

			Reasonable	Maximum
k_b	43	43	156	156
i_b (10^{10})	2	4	4	10
β^* (m)	11	11	11	11
intensity per beam	$8.6\ 10^{11}$	$1.7\ 10^{12}$	$6.2\ 10^{12}$	$1.6\ 10^{13}$
beam energy (MJ)	.06	.12	.45	1.1
Luminosity ($cm^{-2}s^{-1}$)	$2\ 10^{28}$	$7.2\ 10^{28}$	$2.6\ 10^{29}$	$1.6\ 10^{30}$
event rate [1](kHz)	0.4	2.8	10.3	64
W rate [2] (per 24h)	0.5	3	11	70
Z rate [3] (per 24h)	0.05	0.3	1.1	7